REFERENCES

(1) N. A. Armstrong and G. A. March, *J. Pharm. Sci.*, **63**, 126(1974).
(2) *Ibid.*, **65**, 198(1976).
(3) R. E. King, in "Remington's Pharmaceutical Sciences," Mack Publishing Co., Easton, Pa., 1970, p. 1653.
(4) C. E. Capes, *Powder Technol.*, **4**, 77(1971).
(5) J. Jaffe and I. Lippmann, *J. Pharm. Sci.*, **53**, 441(1964).
(6) F. Prescott, *Drug Cosmet. Ind.*, **97**, 497(1965).
(7) M. Bornstein, J. P. Walsh, W. J. Munden, and J. L. Lach, *J. Pharm. Sci.*, **56**, 1410(1967).
(8) H. P. Frank, S. Barkin, and F. R. Eirich, *J. Phys. Chem.*, **61**, 1375(1957).
(9) R. E. Phares, *J. Pharm. Sci.*, **57**, 53(1968).
(10) K. Ridgway and M. H. Rubinstein, *J. Pharm. Pharmacol.*, **23**, 11S(1971).
(11) F. W. Goodhart, M. E. Everhard, and D. A. Dickcius, *J. Pharm. Sci.*, **53**, 338(1964).
(12) G. Zografi and A. M. Mattocks, *ibid.*, **52**, 1103(1963).
(13) P. Fuchs, *Arch. Pharm.*, **303**, 471(1970).

ACKNOWLEDGMENTS AND ADDRESSES

Received March 10, 1975, from the *Welsh School of Pharmacy, University of Wales Institute of Science and Technology, Cardiff, United Kingdom.*

Accepted for publication May 5, 1975.

The award to G. A. March of a research scholarship by the Pharmaceutical Society of Great Britain and the help of Merck Sharp & Dohme Research Laboratories are gratefully acknowledged.

* Present address: I.C.I. Pharmaceuticals Division, Macclesfield, United Kingdom.

ˣ To whom inquiries should be directed.

Constant Returns to Scale for Prescription Dispensing in U.S. Community Pharmacy

DAVID LOHRISCH *, S. CABELL SHULL ‡, and MICKEY C. SMITH *ˣ

Abstract □ By using data from a sample of 1767 community pharmacies, a total cost function was estimated by a polynomial regression of total cost on output. The Cobb–Douglas production function was estimated by a multiple linear regression of natural logarithmic transformations of output on natural logarithmic transformation of labor and capital. No economies of scale were found in prescription departments. Cost data led to a conclusion of constant marginal costs.

Keyphrases □ Prescription dispensing—community pharmacies, total cost function in relation to size, Cobb–Douglas production function □ Cobb–Douglas production function—community pharmacies, prescription dispensing, total cost in relation to size □ Pharmacies—total cost function in relation to size, prescription dispensing, Cobb–Douglas production function

The pervasive economic influence of the 1970's is inflation with an associated recession. The news media daily report on the state of the economy and profusely illustrate their conclusions by examples from agriculture and industry. These two sectors of the economy at least have the advantage of being well studied and somewhat understood.

The service industries are not so fortunate. Only one cost and scale study (of the U.S. Postal Service) was published in recent years (1). The health service industries have been subjected to some indepth studies. Most of these have concentrated on output specifications (2) and cost functions (3), resulting in seven hospital investigations reporting increasing returns to scale and three with constant returns. A production function was calculated (4) for medical office practice, but no economies of scale were calculated.

Many studies have concerned pharmacy and prescription costs (5–8). But there has been a dearth of studies concerning economies of scale in the health services and pharmacy practice generally. The purpose of this study was to find what, if any, economies of scale exist in the prescription dispensing operations of U.S. community pharmacies.

THEORETICAL

Economies of scale, or increasing returns to scale, may be defined as the proportional increase in output greater than the proportional increase in each input. If the proportional increase in output is less than the proportional increase in inputs, or equal to them, then the firm is experiencing decreasing returns to scale or constant returns to scale, respectively.

These economies of scale are due to the following factors (9):

1. Bulk transactions of materials—the ease of dealing with large quantities of materials reduces unit costs.
2. Pooled reserves—operating on a large scale reduces the cost of uncertainty through a spreading of the risk.
3. Multiples—the costs of personnel and machines fall with increasing size due to their indivisibilities.

The neoclassical theorists thought that diseconomies of scale would be manifest in the form of managerial inefficiencies with increasing size (10). In addition, the increasing division of labor might be taken so far that employees would become bored and inefficient with their highly specialized and repetitive tasks. On the other hand, it has been suggested that with the increasing usage of computers in large industry, the expected inefficiencies have not occurred, resulting in constant rather than decreasing returns to scale.

Economies of scale are closely related to both cost and production functions. Depending on the design of the study, economies of scale may be investigated by an examination of the shape of the marginal cost function or an examination of the parameters of the Cobb–Douglas production function.

The marginal cost is, mathematically, the derivative with re-

Table I—Analysis of Variance for the Polynomial Regression

Source of Variance	Mean Square Regression	*df* Regression	Mean Square Error	*df* Error	*F* Calculated	Variance Explained
Linear	3501.011	1	1.08364	1372	1109.88[a]	0.7019
Quadratic	24.191	1	1.06678	1371	22.68[a]	0.7068
Cubic	8.569	1	1.06131	1370	8.07[a]	0.7084
Quartic	5.972	1	1.05772	1369	5.64[a]	0.7096
Quintic	10.545	1	1.05079	1368	10.04[a]	0.7118
Sextic	7.905	1	1.04577	1367	7.56[a]	0.7134
Seventh order	1.174	1	1.04568	1366	1.12	—

[a] Significant *F* values.

spect to the output of the total cost function. Total cost is a relationship between total costs and output, the most common form being quadratic or linear:

$$TC = A + BY + CY^2 + E \quad \text{(Eq. 1)}$$

$$TC = A + BY + E \quad \text{(Eq. 2)}$$

where TC = total costs and Y = output.

With these two forms, the derivative (marginal cost) may be constant or a function of output, with marginal cost either increasing or decreasing with increasing outputs: (*a*) increasing returns to scale, Eq. 1 with C negative; (*b*) constant returns to scale, Eq. 2; and (*c*) decreasing returns to scale, Eq. 1 with C positive.

A production function may be defined as a physical technical relationship between the output of a well-defined good or service and the various inputs used in its production, within the existing state of technology (11). Production functions may be determined by cross-sectional or time series analysis of the data. A time series analysis follows the behavior of one firm over time, while a cross-sectional analysis studies the behavior of a sample of firms at one point in time.

A production function may be of an aggregate form, which aggregates data from all firms in an industry to obtain an industry production function, or a micro form, in which the data are obtained from individual operating units to describe the (average) operation of the units.

The Cobb–Douglas production function is a popular log–linear estimator of production. Factor inputs of labor and capital are exponentially related to output. This type of analysis results in a three-dimensional production surface, a statistical estimate of the maximum production point of each producing unit (12):

$$Y = AL^{\alpha}C^{\beta} \quad \text{(Eq. 3)}$$

where Y = output, L = units of labor input, C = units of capital input, α = elasticity of production with respect to labor, β = elasticity of production with respect to capital, and A = constant. With increasing returns to scale, $\alpha + \beta > 1$; with constant returns to scale, $\alpha + \beta = 1$; and with decreasing returns to scale, $\alpha + \beta < 1$.

This function may be linearized by taking natural logarithms of both sides:

$$\ln Y = \ln A + \alpha \ln L + \beta \ln C \quad \text{(Eq. 4)}$$

The Cobb–Douglas production function only describes firms that have undergone the same economies of scale throughout the whole range of outputs. It is not applicable in cases where economies of scale change from increasing returns to scale to constant returns to scale. For the different regions of production, different production functions must be used.

EXPERIMENTAL

Study Population—Cost and operational data[1] on 1767 community pharmacies for the calendar year 1972 were available. Due to incomplete data from some pharmacies, only 1374 pharmacies were used in the study. The items supplied were:

1. Prescription sales (1972)
2. Total store sales (1972)
3. Cost of advertising (1972)
4. Depreciation allowance (1972)
5. Delivery costs (1972)
6. Rent (1972)
7. Heat and light (1972)
8. Total expenses (1972)
9. Prescription department inventory
10. Proportion of prescription sales to total sales
11. Proportion of prescription department area to total area
12. Number of prescriptions dispensed (1972)
13. Number of hours worked each week by the manager
14. Number of hours worked each week by professional employees

Means tests were performed to determine if there were any statistical differences between the pharmacies used and those rejected. No differences were found on any of the variables used at the 0.05 level.

Variables—All variables were adjusted to reflect only the prescription department.

The output of community pharmacy may be expressed as an aggregation, *i.e.*, some weighting of separate outputs in a common unit of measure such as dollar value (the value added approach), or in a disaggregated manner using innumerable units. In this study the latter route was taken. The output of community pharmacy was defined as the prescription service associated with the dispensing of a prescription. As the output measure, the number of prescriptions dispensed for the year was used.

The change in quality of this service during the study (1 year) was considered negligible.

The total cost was found by allocating total expenses for the pharmacy to the prescription department. The best method of cost allocation is direct separation of expenses of various departments. Unfortunately, the nature of the data was such that no expense items could be separated for the prescription area directly.

As a compromise, rent, heat, and light were allocated in proportion to the space utilized, since the cost of these items is dependent on area. Depreciation is a function of investment in capital. Since investment figures were unavailable, it was decided that equipment (fixtures and office machines) was better allocated on the basis of area rather than the alternative method of relative sales.

The remaining costs were allocated on the basis of the proportion of prescription sales to the total sales (13).

Cobb–Douglas production functions were originally applied to manufacturing industries, and measures of capital were tailored to fit these industries. Capital was taken as the value of plant, buildings, tools, and machinery (14). The annual rent paid by a pharmacy is a measure of the total value of the buildings. Similarly, the value of fixtures and equipment is expressed in the depreciation figure allowed for this item in the accounts of the firm.

Working capital in a retail establishment is an important part of the capital requirements. The value of the prescription department inventory was used as a substitute for this working capital since no other measure was available. Capital was obtained by summing allocated rent, depreciation, and inventory.

Table II—Statistics on Coefficients of Multiple Regression

Variable	Regression Coefficient	Standard Error of Regression Coefficient	*t* Value
Capital	0.66761	0.02473	26.996
Labor	0.34889	0.02148	16.244

[1] Data taken from Lilly Digest compilations, supplied by Eli Lilly & Co.

Labor was defined as the number of hours worked in the prescription department by professionals. No data were available for the time spent by nonprofessionals in prescription-related work. Employee pharmacists were considered as spending 100% of their time in the prescription department, while the pharmacist/manager divided his or her time in production to the relative sales of the prescription department and the remainder of the store. The measure of labor input was then equal to the sum of these two values for the year.

Functions—The total cost function was estimated by a polynomial regression of total cost on output.

The Cobb–Douglas production function was estimated by a multiple linear regression of natural logarithmic transformations of output on natural logarithmic transformations of labor and capital.

RESULTS AND DISCUSSION

Total Cost Function—The large sample size made the use of available polynomial regression programs impossible. The source program of BMD05R (15) was obtained, and its capacity was altered so that a seventh-order polynomial regression could be performed on the sample of 1374. Table I shows the analysis of variance for the regression. The table F value used to test significance of regression was $F_{1,1000,0.05} = 3.85$ (16).

The coefficients of regression were tested for difference from zero by the following t test (17):

$$t_{N-2} = \frac{bi - 0}{SeRC} \qquad \text{(Eq. 5)}$$

where bi = regression coefficients, N = sample size, and $SeRC$ = standard error of regression coefficient using the t value (18):

$$t_{1000,0.05} = 1.96 \qquad \text{(Eq. 6)}$$

For the purpose of this study, only first- and second-order terms were of value (19). Even so, all of the nonlinear terms together only explain an additional variance of 1.15% above the linear term.

Of the two relevant equations:

$$Y = 1921 + 1.13346X - 0.02263X^2 \qquad \text{(Eq. 7)}$$

$$Y = 4768 + 1.14793X \qquad \text{(Eq. 8)}$$

where Y = predicted total cost, and X = output. Equation 7 has a maximum value of 25 prescriptions; between 50 and 51 prescriptions, the total cost becomes less than the intercept. This curve clearly does not explain the real world and was rejected in favor of Eq. 8.

With a linear total cost function, marginal cost is constant at 1.14793. This finding leads to the conclusion that costs do not change with increasing size of the pharmacy.

Production Functions—A Cobb–Douglas production function was estimated using the multiple regression program BMD03R (20). An F-test ($F_{2,1371,0.05}$) was performed on the regression, and the value of 1060.0 was found to be significant. Table II shows the coefficients of labor and capital and the t-values associated with them. Both values of t were significant at the 0.05 level.

The sum of the coefficients was equal to 1.01650, which was not significantly different from one at the 0.05 level. This value was determined by a t test given by Murphy (21).

CONCLUSIONS

In this study, two different approaches were used to arrive at the same conclusion. No economies of scale were found in U.S. community pharmacy prescription departments. Constant marginal costs were found, based on cost data. The sum of the coefficients of the Cobb–Douglas production function coefficients was found to be unitary, pointing to constant returns to scale based on production data.

These results show that there is no difference between the economies of operation of the prescription departments of small pharmacies and larger ones. Apart from factors not considered in this study such as differences in cost of goods sold, a small pharmacy should be able to compete with a larger one in the prescription area but not necessarily in other areas such as nonprescription products or health and beauty aids.

REFERENCES

(1) L. Merewitz, *J. Amer. Statist. Ass.*, **66,** 504(1970).

(2) S. E. Berki, "Hospital Economics," D.C. Heath, Lexington, Mass., 1972, p. 51.

(3) J. R. Lave, *Inquiry,* **3,** 57(May 1966).

(4) R. M. Bailey, in "Empirical Studies in Health Economies," H. E. Klarman, Ed., Johns Hopkins Press, Baltimore, Md., 1970, p. 255.

(5) R. A. Gosselin and Co., "Pharmacy Charges for Prescription Drugs under Third Party Programs," report prepared for N.A.R.D./N.A.C.D.S., May 5, 1971.

(6) M. D. Jacoff, Ph.D. dissertation, Purdue University, Lafayette, Ind., 1961.

(7) S. E. Berki, J. W. Richards, and A. Weeks, "Prescription Dispensing in Twenty Pharmacies: Characteristics, Utilizers, Service, and Costs," report of a study conducted for the Social Security Administration, 1971.

(8) M. J. Myers, presented at the Economics and Administrative Sciences Section, APhA Academy of Pharmaceutical Sciences, Montreal, Canada, May 19, 1969.

(9) J. Johnston, "Statistical Cost Analysis," McGraw-Hill, New York, N.Y., 1960, p. 21.

(10) R. H. Leftwich, "The Price System and Resource Allocation," 4th ed., Dryden Press, Hinsdale, Ill., 1970, p. 164.

(11) A. A. Walters, *Econometrica,* **31,** 1(1963).

(12) P. H. Douglas, *Amer. Econ. Rev.,* **38,** 1(1948).

(13) M. D. Jacoff, Ph.D. dissertation, Purdue University, Lafayette, Ind., 1961, p. 8.

(14) P. H. Douglas, *Amer. Econ. Rev.,* **38,** 12(1948).

(15) "Biomedical Computer Programs," W. J. Dixon, Ed., University of California Press, Berkeley, Calif., 1971, p. 289.

(16) "Scientific Tables," K. Diem and C. Lentner, Eds., Ciba-Geigy Ltd., Basle, Switzerland, 1970, p. 40.

(17) J. L. Murphy, "Introductory Econometrics," Richard D. Irwin, Homewood, Ill., 1973, p. 212.

(18) "Scientific Tables," K. Diem and C. Lentner, Eds., Ciba-Geigy Ltd., Basle, Switzerland, 1970, p. 35.

(19) A. A. Walter, *Econometrica,* **31,** 45(1963).

(20) "Biomedical Computer Programs," W. J. Dixon, Ed., University of California Press, Berkeley, Calif., 1971, p. 258.

(21) J. L. Murphy, "Introductory Econometrics," Richard D. Irwin, Homewood, Ill., 1973, p. 228.

ACKNOWLEDGMENTS AND ADDRESSES

Received November 29, 1974, from the **Department of Health Care Administration and the ‡Department of Economics and Finance, University of Mississippi, University, MS 38677*

Accepted for publication March 10, 1975.

Presented at the APhA Academy of Pharmaceutical Sciences, New Orleans meeting, November 1974.

Supported in part by the Research Institute of Pharmaceutical Sciences, University of Mississippi. Assistance of Eli Lilly and Company, through the office of Mr. William Turenne, is gratefully acknowledged.

[x] To whom inquiries should be directed.